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(54) IMPROVEMENTS IN OR RELATING TO RESPIRATORS

(71) I, THE SECRETARY OF STATE FOR DEFENCE, London, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to respirators which are fitted with a filtering system so that the surrounding atmosphere can be inhaled therethrough.

Respirators are generally fitted on to or enclose only part of the body of a person or animal, and difficulties have been experienced with existing respirators in the maintenance of an effective seal between the edges of the respirator and the skin, or even between any mating parts of the respirator. The complete exclusion from the inhaled air of the atmosphere outside the respirator has thus not been effectively assured. These conditions can be tolerated if the atmosphere contains only unpleasant or disabilitating contamination in mild concentrations. They cannot, however, be tolerated if the atmosphere contains substances which are toxic even in very small doses.

The control of peripheral leakage in a conventional face mask type of respirator is greatly impeded by variations in factors such as face contour, head size and harness tightness, and beard growth and skin conditions, and it is generally impossible to assure a leak-proof seal, especially when face masks cannot be made to fit individual faces without considerable expense.

In the case of a face mask type respirator inward leakage of air can occur during inhalation when the internal pressure is below the external atmospheric pressure. This inward leakage can be eliminated by maintaining the internal mask pressure above atmospheric pressure at all times, so that any leakage is then outwards. Manual or foot operated bellows, and electric or clockwork driven fans have been used to generate the required pressure, but these have obvious disadvantages and limitations.

It is an object of the present invention to provide a respirator wherein a pressure greater than atmospheric pressure is maintained using means which do not involve the wearer in either carrying a significantly greater or cumbersome burden or doing extra work, and which are not expendable in the operational life of the respirator.

According to the present invention, a respirator comprises an outer face mask, an inner face mask spaced from the outer face mask when worn, an inhalation duct through which uncontaminated air may be inhaled by the wearer at a pressure lower than atmospheric pressure, a non-return valve offering a resistance to the passage of exhaled air through which exhaled air may be exhausted from the inner mask to the atmosphere surrounding the outer mask at a pressure greater than atmospheric pressure and a respiratory cycle operated pump which may be operated during exhalation by the pressure difference between the exhaled air and atmospheric pressure to draw uncontaminated air into a chamber and during inhalation by the pressure difference between the inhaled air and atmospheric pressure to discharge uncontaminated air from the chamber to the space between the inner and outer face masks and thereby maintain uncontaminated air at a pressure higher than atmospheric in said space.

Preferably a primary inlet non-return valve is sited in the inhalation duct so that it prevents the throughflow of exhaled air, and the pump communicates with the inhalation duct downstream of the primary inlet non-return valve. The chamber associated with the pump may communicate with the space between the outer and inner face masks through a secondary exit non-return valve arranged to prevent the flow of gas from the space to the chamber, and the chamber may also be adapted to communicate with

a supply of uncontaminated air whose return flow to the supply is prevented possibly by a secondary inlet non-return valve. During use of a respirator having the pump and chamber, primary inlet and exit non-return valves and secondary inlet and exit non-return valves, the primary exit and secondary inlet valves would be closed and the primary inlet valve open during inhalation and the lower than atmospheric pressure in the inhalation duct would cause the pump to close the chamber so that air would be driven from it through the secondary exit valve to the space enclosed between the inner and outer masks.

The supply of uncontaminated, breathable air is advantageously provided in means attached to the respirator, for cleaning atmospheric air e.g. a filter, which will clean the air of contamination dangerous to the wearer and supply him with air suitable for respiration and at the required pressure. The air supplied to the chamber need not necessarily be breathable, but must be uncontaminated. If desired the chamber may be connected to the inhalation duct upstream of the primary inlet non-return valve.

According to a further feature of the invention the pump and the chamber are each a bellows arranged with their end walls so linked that the two bellows will open and close simultaneously. The corresponding end walls of the bellows may be contiguous. The smaller chamber bellows is conveniently fitted normally concentrically, inside the first bellows. The bellows may be constructed of a plastics material such as polyvinylchloride.

The invention is particularly suitable for face-masks or respirators having an outer mask which fits on to the wearer's face, and an inner mask comprising for example, an ori-nasal mask covering the wearer's nose and mouth. A buccal mask and a nose clip could be used, however. These are then capable of eliminating seepage of any of the surrounding atmosphere under their edges.

Although the invention is very advantageously employed in face masks particularly for use in toxic atmospheres, it could be employed in respirators covering a much larger part of the body, such as helmets or suits, for example, when leakage is at risk.

In order that the invention may be more clearly understood, the main elements of a respirator in accordance with the invention will now be described followed by three different respirators possessing these elements in various forms, by way of example, with reference to the drawings filed with the provisional specification, of which:—

Figure 1 is a general diagrammatic layout of the main elements of a respirator in accordance with the invention,

Figure 2 is a diagrammatic cross-sectional view of an integral canister type respirator,

Figure 3 is a diagrammatic cross-sectional view of a double container type respirator,

Figure 4 is a diagrammatic cross-sectional view of the mask of a detached bellows type of respirator, and

Figure 5 is a diagrammatic cross-sectional view of the detached bellows of the respirator shown in figure 4.

As shown in figure 1 the main elements of a respirator according to the invention are a face mask 1 having an inner ori-nasal mask 2 covering the nose and mouth alone, a filter unit 3, and a bellows chamber 4. The filter unit 3 communicates with the interior of the ori-nasal mask 2 via a primary duct 5 having a non-return valve 6 which permits air flows from the unit 3 to the mask 2 only. The ori-nasal mask 2 is also exhausted to atmosphere via a non-return valve 7 which prevents inward flow and has a small but definite resistance to outward flow. The bellows chamber 4 contains an outer bellows 8 and an inner bellows 9 concentrically mounted with stiff common end walls so that they are mutually co-operating. The wall of the chamber 4 is vented to atmosphere at 16. A pipe 10 connects the interior of the outer bellows 8 with the duct 5 between the non-return valve 6 and the ori-nasal mask 2. A pipe 11 connects the duct 5, between the filter unit 3 and the non-return valve 6, with a space 12 between the ori-nasal mask 2 and the face mask 1. There are two non-return valves, 13 and 14, in the pipe 11, which prevents flow in the pipe in a direction from the space 12 to the duct 5. Between the two valves 13 and 14, a pipe 15 connects the pipe 11 with the interior of the bellows 9.

The operation of the respirator is as follows. When the wearer inhales, air is drawn through the filter unit 3 and cleaned. It passes through the duct 5 and the valve 6 to the interior of the ori-nasal mask 2. The valve 7 is, of course, closed. Because there is a small but definite resistance to the passage of air through the filter unit 3 and possibly through the valve 6, air is simultaneously drawn by the inhaling wearer from the outer bellows 8, which closes, closing the inner bellows 9 also. When the wearer exhales, air is exhausted against a small back pressure from the valve 7. The valve 6 is closed, and the consequential rise in pressure caused by the back pressure in the valve 7 is conveyed to the pipe 10 and the outer bellows 8, causing it to open. The opening of the outer bellows 8 opens also the inner bellows 9, which sucks air from the filter unit 3 via the pipe 11, the non-return valve 13, and the pipe 15. The valve 14 is closed because the pressure in the space 12 is higher than that in the bellows 9. When the wearer next inhales, and the

bellows 8 and 9 are caused to close, the air in the inner bellows 9 is pumped via the non-return valve 14 to the space 12. The valve 13 is closed because its downstream pressure is higher than that upstream. The pressure in the space 12 is thus maintained above that of the atmosphere at the vital time during inhalation, and ingress of unfiltered atmosphere is prevented. Since the air in the space 12 becomes composed of unbreathed filtered air at ambient humidity misting of the mask's windows, and discomfort to the wearer are minimised.

The bellows system could be replaced by a piston/cylinder but this would be less efficient and more liable to leak. To prevent the wearer from being in any danger should the bellows spring a leak, the air supply system may be modified so that only cleaned air surrounds the bellows. For example, referring to figure 1, if the bellows chamber 4 was not vented but received the pipe 11 instead, and the free end of the bellows 9 contained the valve 13, clean air would then surround the bellows in the chamber 4 during its path to the space 12.

The three different types of respirator to be described now all possess the elements described with reference to figure 1. These respirators are the integral canister type, the double container type, and the detached bellows type.

The integral canister type respirator shown in figure 2 has a facemask 20 and an ori-nasal mask 21 mounted on a tube 22 extending from the mask 20.

The tube 22 communicates with a main tube 23 in a canister 24, the canister 24 being airtightly, and detachably, mounted in a projection 25 from the mask 20. The canister 24 has air-inlets 26 in an end wall, and contains a particulate filter 27 and a charcoal filter 28 filling an annulus between the main tube 23 and the outer wall of the canister 24. A plate 29 is fixed across the interior of the canister 24 to form a compartment or bellows chamber 30 in the end of the canister remote from the inlet 26. An outer bellows 31 is airtightly attached to the plate 29 and the canister has vents 32 to atmosphere. An inner bellows 33 is mounted inside the bellows 31 as described above with reference to figure 1. An annular plate 34 is fitted between the tube 23 and the outer wall of the canister to form a cylindrical compartment bounded by the plates 29 and 34, and in open communication with the tube 23. Non-return valves 35 in the plate 34 permit the passage of air from the filters 27 and 28 to the tube 23 while openings 36 in the plate 29 permit the flow of air between the tube 23 and the interior of the outer bellows 31. A tube 37 connects the inner bellows 33 with an annular space 38 in the projection 25, and a non-return valve 39 in the plate 34 permits the flow of filtered air to the bellows 33 via a tube 40. A non-return valve 41 permits the flow of exhaled air from the tube 23 to the atmosphere. This valve 41 also maintains a small back pressure to the exhaust flow. The annular space 38 is sealed from the tubes 22 and 23 by a rubber washer 42 and is in communication with the space between the mask 20 and the ori-nasal mask 21, via a passage 43 and a non-return valve 44.

The mode of operation of the internal canister type respirator is as follows. When the wearer inhales, air is drawn into the canister 24 via the inlets 26, passes through the filters 27 and 28, and the non-return valves 35 into the tubes 23 and 22 and thence to the ori-nasal mask 21 and the wearer's lungs. During inhalation the air pressure in the tube 23 is below atmospheric pressure so that the valve 41 is held closed, and this depression is communicated to the interior of the outer bellows 31 by the openings 36, so that the bellows 31 closes. During exhalation, when air vents to atmosphere from the tube 23 via the non-return valve 41, air pressure in the tube 23 is above atmospheric pressure because of the back pressure of the valve 41; the valves 35 and 44 are closed and the bellows 31 is urged open. The inner bellows 33 is thereby opened also and air is drawn into it from the filters 27 and 28 via the valve 39 and the tube 40. During inhalation, when both bellows 31 and 33 are being urged to close the valve 39 closes and air is driven from the bellows 33, through the tube 37, the space 38, the passage 43 and the valve 44, into the space between the masks 20 and 21 whereby a pressure greater than atmospheric pressure is produced in the latter space.

The double container type respirator shown in figure 3 has a face-mask 50 and an ori-nasal mask 51. Two canisters 52 and 53 are detachably and airtightly fitted on mountings 54 and 55 respectively, in a walled chamber 56 of the mask 50. The canister 52 has an inlet 57 at its outer end. It contains a particulate filter 58 and a charcoal filter 59. A non-return valve 60 is fitted in the mounting 54, whereby air is permitted to flow through the valve 60 and through a duct 61 connecting the chamber 56 with the interior of the ori-nasal mask 51. The chamber 56 is sealed from the space between the masks 50 and 51. Between the filter 59 and the valve 60 there is an air chamber 62.

The canister 53 has a vent 63 in its outer end and a fixed plate 64 across its interior near to its inner end. Contained in the compartment between the vent 63 and the plate 64 is a main bellows 65, attached to the plate 64 at its inner end. An inner bellows 66 is mounted, as described before, inside the bellows 65. Vents 67 and 68 in

the plate 64 and in the mounting 55 respectively allow the passage of air between the interior of the main bellows 65 and the chamber 56. A valve box 69 containing two non-return valves 70 and 71, is mounted in the chamber 56. A tube 72 connects the chamber 62 with the valve box 69 at the inlet side of the valve 70. A tube 73 connects the interior of the inner bellows 66 with that of the valve box 69 between the two valves 70 and 71, while another tube 74 connects the valve box at the outlet side of the valve 71 with the space between the masks 50 and 51. The chamber 56 is vented to atmosphere by a non-return valve 75 which is capable of exerting a small back pressure on exhaust airflow.

The mode of operation of the double canister respirator is as follows. During inhalation, air is drawn through the vent 57 in the canister 52 and through the filters 58 and 59 into the chamber 62. Thence it passes through the valve 60, the chamber 56 and the duct 61, to the interior of the ori-nasal mask 51. The air in the chamber 56 is at a pressure less than that of the atmosphere, and this low pressure is communicated via the vents 67 and 68 to the interior of the bellows 65, which closes. During exhalation through the duct 61, the chamber 56, and the valve 75, a pressure higher than that of the atmosphere is built up in the chamber 56, and the bellows 65 is caused to open, thus opening the inner bellows 66. The bellows 66 sucks filtered air through the tube 73 and the valve 70, the valve 71 being closed, and through the tube 72 from the chamber 62 in the mounting 54. When the wearer inhales, the closing of the main bellows 65 forces the inner bellows 66 to close as well, and to pump air via the tube 73 and the valve 71, the valve 70 being closed, through the tube 74 to the space between the masks 50 and 51.

The detached bellows respirator has a mask 80 illustrated in figure 4 and a canister 81, which may be clipped to the clothing of the wearer, illustrated in figure 5. The mask 80 has an air bag edge 82 and a forward mounting 83. An ori-nasal mask 84 is fitted to the mounting 83. The mounting 83 provides an air chamber 85 which is ducted to the mask 84 and is vented to atmosphere by a flexible non-return valve 86. A duct 87 connects the chamber 85 with an air filter container 88 attached to the face-piece 80; via a non-return valve at 89. A speech transmitter unit 90, containing the non-return valve 86, is fitted to the mounting 83.

The canister 81 comprises an auxiliary filter 91, which is vented from atmosphere at 92 and is connected to a chamber 93 via a non-return valve 94. In a main compartment 95 of the canister 81 is a main bellows 96 having an inner bellows 97 mounted in a manner similar to that of the bellows of the other respirators described above. The compartment 95 is vented to atmosphere via vents 98. The main bellows 96 is connected via a tube 99 to the chamber 85, in the mounting 83 in the mask 80. The inner bellows 97 communicates directly with the chamber 93 which is connected via a non-return valve 100 and a tube 101 to the space between the masks 80 and 84.

The operation of the detached bellows respirator is as follows. During inhalation air is drawn through the filter container 88, the valve 89, and the duct 87, to the chamber 85, whence it passes into the ori-nasal mask 84. The below atmosphere pressure set up in the chamber 85 is communicated to the outer bellows 96 by the tube 99, and the bellows closes. When the wearer exhales, the air passes through the chamber 85 and the valve 86 to atmosphere. The higher than atmosphere pressure set up in the chamber 85 by a back pressure from the valve 86 causes the bellows 96 and 97 to open and the bellows 97 draws in air via the vent 92, the filter 91, the valve 94, and the chamber 93. When the bellows closes in inhalation, air is driven from the inner bellows 97 via the chamber 93, the valve 100 and the tube 101 to the space between the masks 80 and 84.

The three particular types of respirator described above operate satisfactorily to maintain an adequate pressure between the face mask and the ori-nasal mask, with outer and inner bellows of about $4\frac{1}{2}$ cm. diameter and 3 cm. diameter respectively, and an effective length of about 3 cm. The pressure obtained is about 3—5 cm. wg. above atmospheric pressure. A satisfactory bellows material is polyvinylchloride with a wall thickness of 0.006 ins.

The invention effectively eliminates ingress of air between the edges of the respirator and the skin of the wearer. The efficiency of protection consequently depends on two other factors only, the efficiency of the filter unit and the prevention of dynamic rearward leakage of the primary exit valve. The filter unit employed in these respirators should have an appropriately high standard of efficiency. The exit valve used gives a high order of protection but this can be improved still further by using a double exit valve comprising two non-return valves separated by a dead space, for example of the type described in British Patent No. 1,077,791.

WHAT I CLAIM IS:—

1. A respirator comprising an outer face mask, an inner face mask spaced from the outer face mask when worn, inhalation duct through which uncontaminated air may be inhaled by the wearer at a pressure lower

than atmospheric pressure, a non-return valve offering a resistance to the passage of exhaled air through which exhaled air may be exhausted from the inner mask to the atmosphere surrounding the outer mask at a pressure greater than atmospheric pressure and a respiratory cycle operated pump which may be operated during exhalation by the pressure difference between the exhaled air and atmospheric pressure to draw uncontaminated air into a chamber and during inhalation by the pressure difference between the inhaled air and atmospheric pressure to discharge uncontaminated air from the chamber to the space between the inner and outer face masks and thereby maintain uncontaminated air at a pressure higher than atmospheric in said space.

2. A respirator according to claim 1 having a primary inlet non-return valve in the inhalation duct arranged so as to prevent the flow of exhaled air therethrough, and wherein the pump communicates with the inhalation duct down-stream of the primary inlet non-return valve.

3. A respirator according to either claim 1 or claim 2 wherein the chamber is in communication with the space enclosed between the masks through a secondary exit non-return valve arranged to prevent the flow of gas from said space to the chamber and the chamber is also adapted to be connected upstream of the secondary exit non-return valve with a supply of uncontaminated air.

4. A respirator according to claim 3 wherein the chamber has a secondary inlet non-return valve through which it is adapted to be connected to the supply of uncontaminated air, the non-return valve being arranged to prevent the flow through it of air from the chamber.

5. A respirator according to claim 4 wherein the chamber communicates via the secondary inlet non-return valve with the inhalation duct upstream of the primary inlet non-return valve.

6. A respirator according to any one of claims 2 to 5 wherein the pump and the chamber are each a bellows arranged with their end walls so linked that the bellows will open and close simultaneously.

7. A respirator according to claim 6 wherein the corresponding end walls of the two bellows are contiguous.

8. A respirator according to either claim 6 or claim 7, wherein the chamber bellows is concentrically inside the pump bellows.

9. A respirator according to any one of the preceding claims, wherein the inner mask comprises an ori-nasal mask for covering the wearer's mouth and nose.

10. A respirator substantially as hereinbefore described with reference to Figure 2 of the drawings filed with the provisional specification.

11. A respirator substantially as hereinbefore described with reference to Figure 3 of the drawings filed with the provisional specification.

12. A respirator substantially as hereinbefore described with reference to Figures 4 and 5 of the drawings filed with the provisional specification.

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Chartered Patent Agent,
Agent for the Applicant.

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1587812 PROVISIONAL SPECIFICATION
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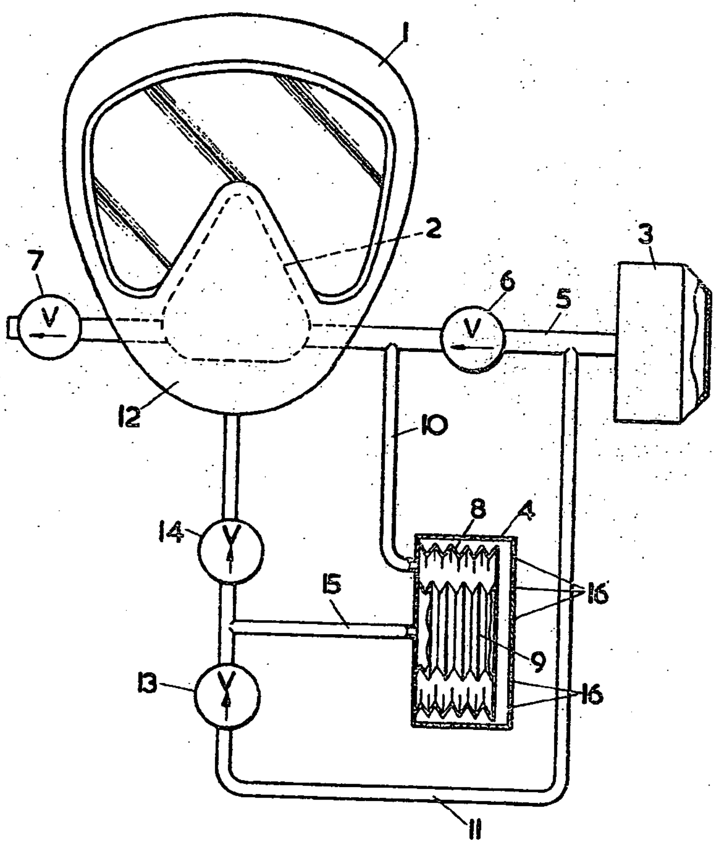

FIG. 1.

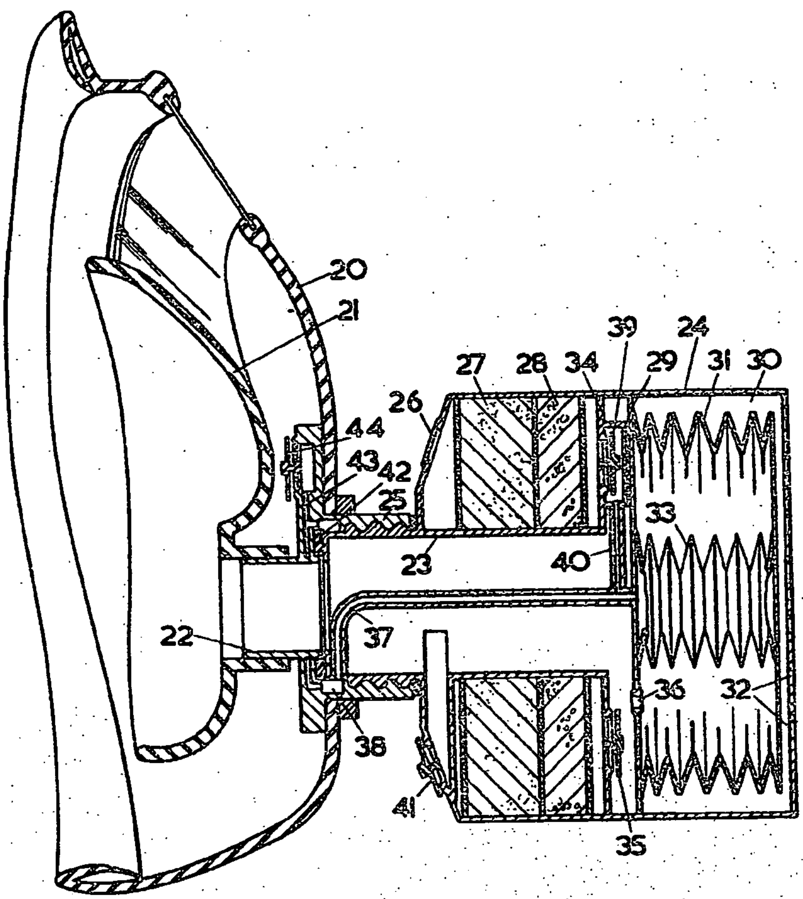
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FIG. 2.

1587812 PROVISIONAL SPECIFICATION

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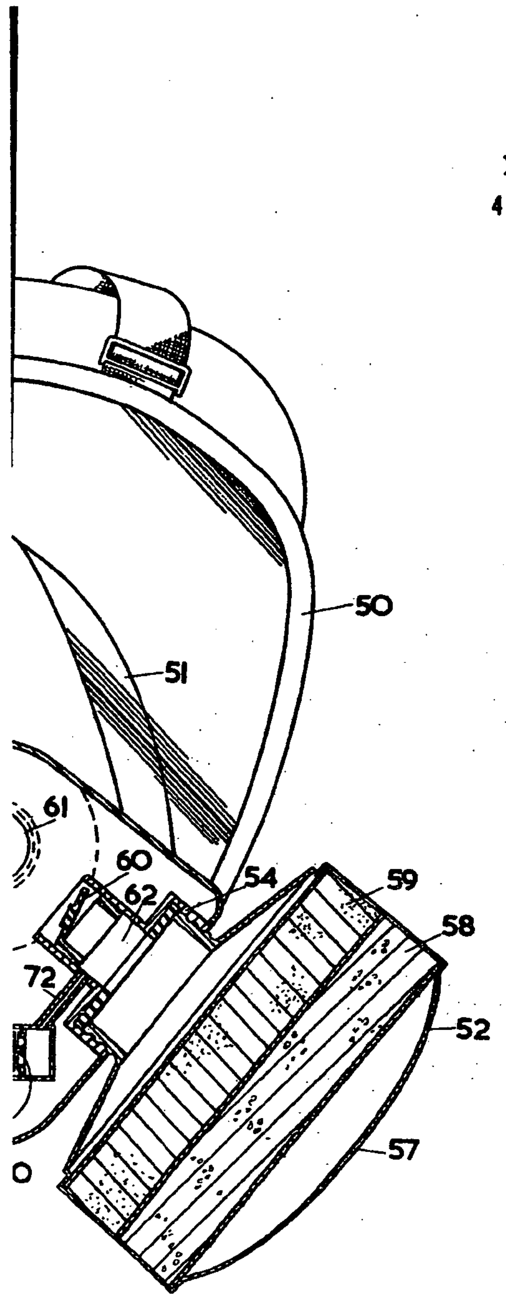
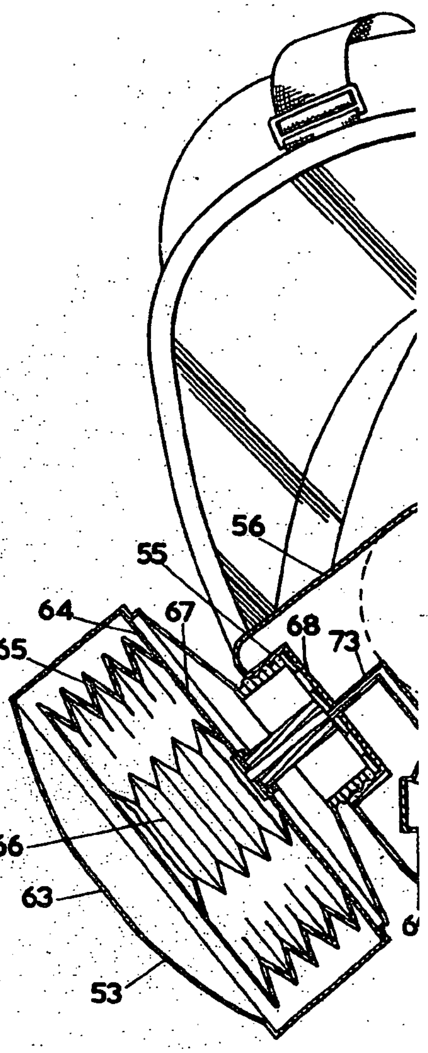
Sheet 3





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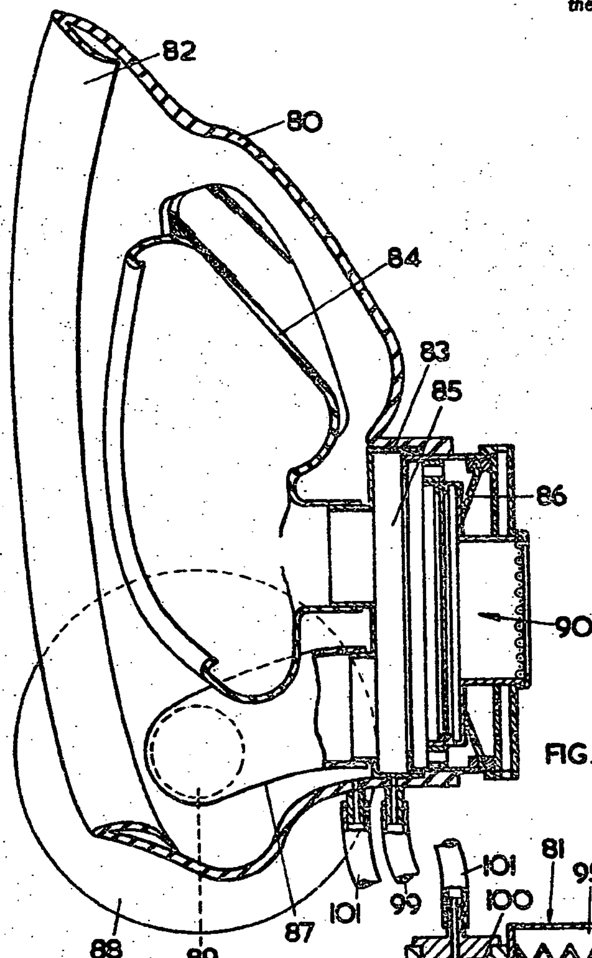
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FIG. 4.

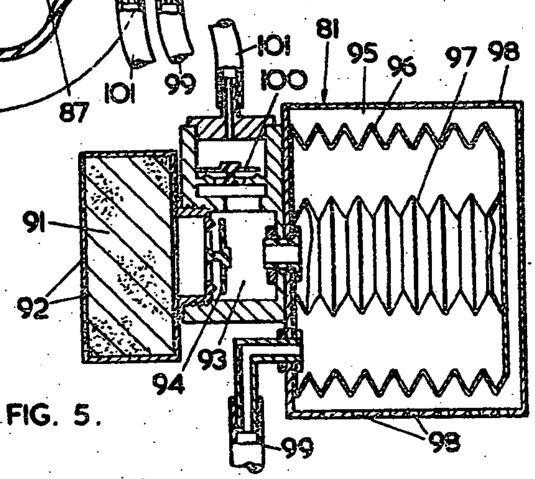
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FIG. 5.